Connecting Inquiry and Values in Science Education: An Approach based on John Dewey's Perspective

Introduction

The results of science surround us and structure our everyday world, and science impacts us almost every moment in our lives. We make numerous decisions on issues related to science during our lifetime, and every time we make such a decision, values are involved, because science is value-laden (Anderson, 2004; Biddle, 2013; Brown, 2012; Douglas, 2000, 2009; Kourany, 2010; Longino, 2002). In fact, values play a role not only in decision-making of science-related issues such as socio-scientific issues, but also in science practice. As Coulo (2014) pointed out, science not only bears on our values in many ways, but science is also affected by values because ethical and political responsibilities of scientific work and knowledge impact scientists and science. Values play an implicit role in the choice of research subjects and research methods (Coulo, 2014). Also individual scientists may choose to engage in certain kinds of research, but different societies and institutions may encourage or discourage them (Forge, 2008). Furthermore, these non-epistemic types of values including ethical, social, and political responsibilities affect science practice because of inductive risk (Douglas, 2000). Therefore teaching and learning about the role of values in science in socio-scientific and controversial issues can play a role in humanizing sciences and illustrating their ethical, cultural and political facets (Matthews, 1994).

A study by Evagorou, Jimenez-Aleixandre, and Osborne (2012) showed an example of how non-epistemic values affected students' decision-making in socio-scientific issues and how little scientific inquiry affected decision-making. When two groups of students with different background were asked to make a decision on a socio-scientific issue, their decisions appeared to be based on their cultural and social background rather than the inquiry that they conducted in the science class. There was little change in their opinions before and after the class, and even though they conducted an inquiry based on various related information, students tended to accept only supporting evidence to their opinions. Students' reasoning for their decisions was not evidence-based (Evagorou et al., 2012). Another study by Nielson (2012) showed that students co-opted science to make it appear that their evaluative claims were solidly supported. Furthermore, students used scientific evidence not only for justifying their claim but also for emphasizing the importance of their claim (Nielsen, 2012).

These are a few of the examples showing that conducting scientific inquiry does not automatically help students make an informed decision using inquiry-based evidence. Scientific inquiry has been emphasized in science education because it is expected to help students understand, evaluate and make an informed decision for science-related issues (American Association for the Advancement of Science [AAAS], 1993; Rutherford & Ahlgren, 1990). K-12 science education has focused on educating all citizens, and people who are well educated in science, whether they are scientists or non-scientists, are expected to possess scientific habits of mind, be capable of engaging scientific inquiry, and to reason well in scientific contexts (National Research Council [NRC], 2012). Overall, they are expected to make an informed

decision when they face a controversial science-related issue. Doing scientific inquiry in the science class, however, seems not become a useful experience for students to make a decision in socio-scientific issues as expected.

In this paper, we explore how to help students use inquiry in decision-making based on John Dewey's perspective. Science education owes a lot to John Dewey's ideas of how science should be viewed and what science education should do (Wong et al., 2001). Unfortunately, although Dewey's ideas can be found in every facet of progressive science education in America and in the international science education, they have been underappreciated or misunderstood in many ways (Wong et al., 2001). Therefore, it is worth returning to Dewey's perspective of inquiry in science and exploring how it is related to decision-making.

A Missing Link in Science Education Standards

Inquiry is central to science learning and a prominent feature of science education standards including *National Science Education Standards* (NRC, 1996), *Inquiry and the National Science Education Standards* (NRC, 2000), and *Benchmarks for Science Literacy* (AAAS, 1993) focus on scientific inquiry. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (NRC, 2012), and the *Next Generation Science Standards* (NGSS Lead States, 2013) also emphasize inquiry through "science and engineering practices" dimension. Meanwhile, decision-making is another important feature that has been emphasized in science education standards.

> In a world filled with the products of scientific inquiry, scientific literacy has become a necessity for everyone. Everyone needs to use scientific information to make choices that arise everyday (NRC, *National Science Education Standards*, 1996, 1p).

> We believe that the education of the children of this nation is a vital national concern. The understanding of, and interest in, science and engineering that its citizens bring to bear in their personal and civic decision making is critical to good decisions about the nation's future (NRC, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas,* 2012, viii).

Making a good decision using scientific information in personal or civic issues is undoubtedly important so that students should learn it through science education. The term "inquiry" is used in two different ways in science education. First, it refers to the abilities and understanding students should develop to be able to conduct scientific investigations and second, it refers to the teaching and learning strategies (NRC, 2000). If inquiry also refers the teaching and learning strategies, it implies that inquiry can be used to learn an informed decision-making.

How conducting inquiry helps students learn an informed decision-making, however, is not explicitly explained in science education standards. Instead, *Benchmarks for Science Literacy* (AAAS, 1993) mentions critical response skills that students need to learn to make judgments based on what they know in science. According to this standard, how to use supporting evidence, the language, and the presented argument is an important skill to make judgments of whether taking the claim in question seriously or not, so students should learn such a skill and practice it to make it a lifelong habit of mind.

> Apart from what they know about the substance of an assertion, individuals who are science literate can make some judgments based on its character. The use or misuse of supporting evidence, the language used, and the logic of the argument presented are important considerations in judging how seriously to take some claim or proposition. These critical response skills can be learned and with practice can become a lifelong habit of mind (AAAS, 1993, 298p).

Learning critical response skills is not, however, enough for students to learn an informed decision-making. First, critical response skills are only for making judgments to accept some claims, and decision-making requires more than a judgment to accept the claim or the proposition. For example, in every decision-making, values are involved. Without considering involved values, accepting a certain claim does not automatically achieve a decision. Second, critical response skills mentioned in the standards are skills to judge a given claim or preposition, not skills to use or learn to do the inquiry. Therefore there is a missing link between scientific inquiry and decision-making. If we do not know how conducting scientific inquiry helps students make an informed decision in science-related issues, the first question we need to explore will be how scientific inquiry is related to decision-making. We explored this question based on Dewey's views of the relationship among scientific inquiry, value judgment in science, and decision-making.

Scientific Inquiry, Value Judgment, and Decision-Making

Scientific inquiry and its contribution to society play a central role in the philosophical and educational work of John Dewey. Dewey (1910/1995) emphasized that science is not only a subject-matter and body of results, but also a process or method. He pointed out that science

education focused too much on teaching a body of ready-made knowledge and not enough on inculcating a method of thinking, in other words, scientific inquiry (Dewey, 1910/1995). For Dewey, the primary goal of science education is to develop students' ability to inquire as a habit of mind. Dewey's emphasis on scientific inquiry is similar to the emphasis made in *Benchmarks for Science Literacy* (AAAS, 1993), *National Science Education Standards* (NRC, 1996), and *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (NRC, 2012). Today, the major goal of science education is for students to achieve science literacy, and scientifically literate people are expected to be able to make informed decisions on the science-related issues that they face in their lives (AAAS, 1993; NRC, 1996, 2012; Rutherford & Ahlgren, 1990). Thus, whether experiences of conducting scientific inquiry can help students in making informed decisions should be the important question to explore. Decision-making requires value judgment. Then the relationship between scientific inquiry and value judgment needs to be examined to explain how scientific inquiry can help students make a decision. *Science for All Americans* described scientific inquiry, values and attitudes as habits of mind (Rutherford & Ahlgren, 1990). Although these concepts were considered as essential, they were only presented in a way that juxtaposed them as separate and independent factors. What seems to be missing here is the connection between scientific inquiry and value judgment. This is the place that John Dewey's idea of scientific inquiry and of the relationship between inquiry and values can be used to make the missing connection.

According to John Dewey, the uses of scientific inquiry can improve students' ability to make value judgment (Webster, 2008). Inquiry and values are not separate but related because

the direction taken by inquiry is under the influence of values (Dewey, 1948a; 1948b). Thus, in science, inquiry should not be guided by inappropriate, external interests as Dewey explained below (Dewey, 1948a).

> The actual course of scientific inquiry has shown that the best interests of human living in general, as well as those of scientific inquiry in particular, are best served by keeping such inquiry "pure" from interests that would bend the conduct of inquiry to serve concerns alien to conduct of knowing as its own end and proper terminus (Dewey, 1948a, p.206).

"Pure" inquiry does not mean value-free ideal in scientific inquiry. Rather, it means that, when scientific inquiry is not misguided by inappropriate interests, it works based on evidence-based thinking, critical thinking and open evaluation, and eventually, it can contribute to make judgments as intellectual as possible (Dewey, 1910/1995; Webster, 2008). The inappropriate, external interests, the "concerns alien to conduct of knowing as its own end and proper terminus," are not all non-epistemic values, but rather, those values arrived at prior to and dogmatically held independently of scientific inquiry. Dewey (1910/1995) warned that if science is succumbed to inappropriate, external interests, it is no longer able to contribute to social and moral ideals, and further, to democracy.

> The modern warship seems symbolic of the present position of science in life and education. The warship could not exist were it not for science: mathematics, mechanics, chemistry, electricity supply, the technique of its construction and management. But the aims, the ideals in whose service this marvelous technique is displayed are survivals of a pre-scientific age, that is, of barbarism. Science has as yet had next to nothing to do with forming the social and moral ideals for the sake of which she is used (Dewey, 1910/1995, p.397).

The military interests behind the warship are precisely the kind of inappropriate, dogmatic, prescientific values that Dewey hopes to keep out of science, in favor of values produced or tested in the course of scientific inquiry. In fact, "when the actual courses of scientific inquiry has shown the best interests of human living (Dewey, 1948a, p.206)," scientific inquiry can contribute to social and moral ideals (Dewey,1910/1995). Therefore Dewey argued that science should focus on what we should do, and not merely on how we would do it (Dewey, 1910/1995). Thinking about what we should do indicates value-laden thinking. So Dewey's argument implies that science is value-laden practice, so making "pure" scientific inquiry should include making a good value judgment. Figure 1 shows the relationship among scientific inquiry, value judgment, and decision-making based on Dewey's view. Values are involved in conducting scientific inquiry, so scientific inquiry needs to include making a good value judgment. In other words, conducting scientific inquiry is a value-laden activity, so making a good scientific inquiry can improve students' ability to make a good value judgment. Thus, Dewey's idea of scientific inquiry and of the relationship between inquiry and values contributes to make the missing connection between scientific inquiry and value judgment in science education standards. Based on Dewey's view, we can see now how scientific inquiry can contribute to make informed decisions. Decision-making requires value judgment. Scientific inquiry can improve the ability to make a value judgment. Therefore scientific inquiry can contribute to make an informed decision through value judgment.

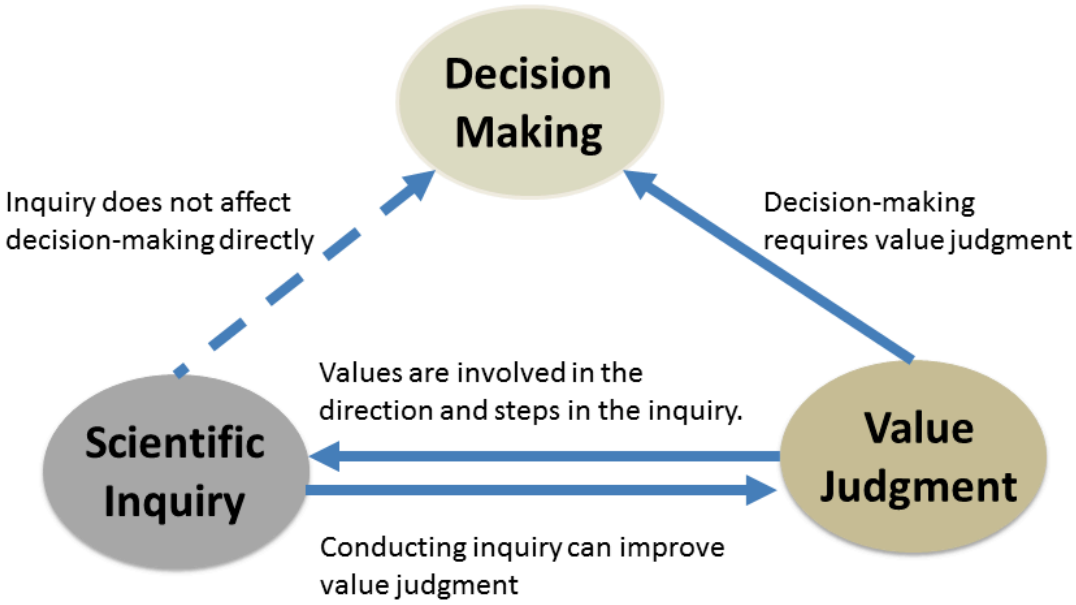

Figure 1. The relationship among scientific inquiry, value judgment, and decision-making in Dewey's view

Practical Value Judgment in Scientific Inquiry

The next question to explore will be how scientific inquiry can improve value judgment. Dewey argued that enforcing obedience to precepts does not do any good to students because it cut off the possibility of learning better ways to live by experimenting with them (Anderson, 2014). Considering Dewey's argument, it would not be appropriate to ask student to accept certain values as precepts when they conduct scientific inquiry, because it will take away the opportunity to do the experiment with various values. Students need to know that various values

can be involved during the inquiry and science education should provide an opportunity to students to conduct inquiries with those various involved values. Dewey suggested that a judgment of value is actually a case of a practical judgment, a judgment about the doing of something.

> A practical judgment has been defined as a judgment of what to do, or what is to be done: a judgment respecting the future termination of an incomplete and in so far indeterminate situation. To say that judgment of value fall within this field is to say two things: one, that the judgment of value is never complete in itself, but always in behalf of determining what is to be done; the other, that judgments of values (as distinct from the direct experience of something as good) imply that value is not anything previously given, but is something to be given by future action, itself conditioned upon (varying with) the judgment (Dewey, 1916, p.230).

The value judgment that students make during the scientific inquiry is also a practical judgment, because, at each step of the inquiry, students need to decide what to do or what is to be done, and values related in that situation will influence the decision. According to Dewey (1916), value judgment can be empirically tested (Anderson, 2014). When students make a value judgment to guide an action, there will be consequences of that particular action, and these consequences will determine if a certain judgement of values is appropriate or not. If students are aware that values are demonstrated in the judgment to guide an action, they can evaluate the values involved in the judgment by evaluating the consequences of the action. Thus, students' value judgment can be empirically tested while they are conducting the scientific inquiry. The uses of scientific inquiry can improve students' ability to make a value judgment (Webster, 2008).

Making a good value judgment can also help scientific inquiry. As a practical judgment, value judgment will be made during the whole process of scientific inquiry. Every time a student decides what to do, values will be involved in that decision of action, whether it is about selecting a particular method, collecting data or interpreting the results. Often, non-epistemic values such as ethical, social, and cultural values are considered to only affect external part of science practice, for example, the selection of hypotheses, restrictions on methodologies, and the use of scientific technologies (Douglas, 2000). These values, however, can also affect internal part of science practice such as statistical significance, evidence characterization, and interpretation of the results, because of inductive risk (Douglas, 2000). This is why science education includes value judgment in scientific inquiry because values affect both external part and internal part of the inquiry that students conduct. For example, social, ethical, or cultural values can influence the selection of hypotheses, so taking these values into account when selecting hypotheses can help students balance open-mindedness with skepticism (AAAS, 1993). Values can also influence in making a methodological choice. Exploring involved values and making value judgments can reduce the chances of choosing methodological options which have ethically unacceptable consequences (Douglas, 2000). Value judgment can also help in evidence characterization, when deciding how to characterize ambiguous data. Questioning and challenging values which might be involved in evidence characterization may help reduce possible errors in dealing with ambiguous data (Douglas, 2000). Value judgment can also help in the interpretation of the results. Not only epistemic values but also non-epistemic values may influence when interpreting the results. Taking a process to evaluate values when interpreting the

results of inquiry will be useful in avoiding interpretational mistakes (Douglas, 2000). Figure 2 shows how value judgment is involved during the scientific inquiry. Values influence the external part of the scientific inquiry such as the direction taken by the inquiry (Dewey, 1948a; 1948b), and are involved in the internal part of the scientific inquiry through practical judgments (Dewey, 2016; Douglas, 2000). Finally values are demonstrated in the judgment made during the inquiry (Brown, 2012; Webster, 2008).

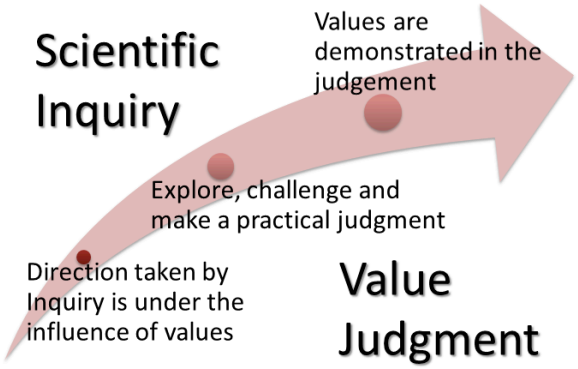

Figure 2. Making value judgment in scientific inquiry

Returning to John Dewey's Perspective

In Dewey's perspective, scientific inquiry and value judgment are closely related to each other. Relating inquiry and values, however, is not unfamiliar idea in science education, because *Science for All Americans* (Rutherford & Ahlgren, 1990) already recognized the interaction between values and science.

> Throughout history, people have concerned themselves with the transmission of shared values, attitudes, and skills from one generation to the next. Even today, it is evident that family, religion, peers, books, news and entertainment media, and general life experiences

> are the chief influences in shaping people's views of knowledge, learning, and other aspects of life. Science, mathematics, and technology can also play a key role in the process, for they are built upon a distinctive set of values, they reflect and respond to the values of society generally, and they are increasingly influential in shaping shared cultural values. Thus, to the degree that schooling concerns itself with values and attitudes, it must take scientific values and attitudes into account when preparing young people for life beyond school (Rutherford & Ahlgren, 1990, p.171).

This recognition, however, faded away in *Benchmarks of Science Literacy* (AAAS, 1993) the following publication after *Science for All Americans* (Rutherford & Ahlgren, 1990). *Benchmarks of Science Literacy* (AAAS, 1993) suggested practical standards for different age groups under the concepts and ideas from *Science for All Americans* (Rutherford & Ahlgren, 1990). There, honesty, curiosity, and balancing open-mindness with skepticism were suggested as scientific values that students should know.

> Honesty is a desirable habit of mind not unique to people who practice science, mathematics, and technology… Curiosity does not have to be taught. The problem is the reverse: how to avoid squelching curiosity while helping students focus it productively… [and] Balancing open-mindness with skepticism may be difficult for students (AAAS, 1993, p.284).

These are descriptions of epistemic values or epistemic virtues shared in science domain, not explanations of how values and science are related. Thus the relationship between values and science was introduced once, but was not pursued further, particularly not to the point of teaching value judgment as part of inquiry. Instead, students were asked to accept values like honesty, curiosity, and balancing open-mindness with skepticism as a sort of precepts. As Dewey pointed out, giving precepts without opportunities to examine them does not do any good to students in science education (Anderson, 2014). Instead of introducing "scientific values" as

precepts, scientific inquiry should provide both intellectual and methodological means to critically evaluate various values based on the idea in *Science for All American* (Rutherford & Ahlgren, 1990) and the idea of John Dewey (Dewey, 2016; Anderson, 2014).

Returning to Dewey's view of inquiry and values can help connecting a missing link between inquiry and values in science education. Table 1 shows a few problems that we recognized in current K-12 science education through *Benchmarks for Science Literacy* (AAAS, 1993), *National Science Education Standards* (NRC, 1996), and *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas* (NRC, 2012). The missing link is that there is not an explicit explanation about how conducting scientific inquiry can help make informed decisions in science-related issues. One way to solve this problem is to explore the relationship between inquiry and values in science because decision-making requires value judgment. The connection between inquiry and values in science, however, are not explicitly explained either. Values in science are not supposed to be explored during the scientific inquiry, and that does not help connecting inquiry and values in science education. Table 1 also shows possible solutions to these problems, based on Dewey's view. According to Dewey (1916; 1948a), scientific inquiry should include good value judgments, and a value judgment in the scientific inquiry is a practical judgment to guide an action which result reflects involved values. Thus, conducting the scientific inquiry can improve students' ability to make a value judgment (Webster, 2008). Considering these ideas, students should be aware of a few things when they conduct inquiry in the science classroom. First, students should know that various values are involved in the scientific inquiry, and those values can be challenged and evaluated. Second,

students should know that they are making a practical value judgment at every step of the scientific inquiry, and they can evaluate the involved values by examining the result of the action. Third, students should know that conducting science inquiry needs to include a good value judgment. Then, connecting inquiry and values in science education can be completed, and the missing link among scientific inquiry and informed decision-making will eventually be connected in science education.

Problems in current science education	**Solutions based on Dewey's view**
Making inquiry does not automatically help making an informed decision.	Decision-making requires value judgment, and making inquiry can improve value judgment. If conducting scientific inquiry includes making a good value judgment, it can eventually help an informed decision-making.
Inquiry and values in science are not explicitly connected.	The direction of the inquiry is under the influence of values. During the inquiry, value judgment has to be a practical judgment, a judgment guiding an action. So the result of the inquiry will include the result of value judgment, and demonstrate involved values.
Values are provided as precepts and not explored during the inquiry.	Making a practical judgment during the scientific inquiry gives students an opportunity to critically evaluate various values and apply them. At each step of the inquiry, students will decide what to do after evaluating various values involved.

Table 1. Problems found in science education and solutions based on Dewey's view

Conclusion

Although there have been more than nine definitions about science literacy through history of science education (DeBoer, 2000), science literacy has been considered as an important goal for students to achieve (AAAS, 1993; NRC, 1996; 2012, Rutherford & Ahlgren, 1990). There is

a certain consensus of describing scientifically literate people as being familiar with the natural world, understanding some of the key concepts and principles in science, having a capacity for scientific ways of thinking, and being able to use scientific knowledge and ways of thinking for personal and social purposes (DeBoer, 2000). Also, scientific inquiry always has been one of essential attributes to achieve science literacy. Naturally, a scientifically literate person is expected to be able to make informed decisions for science-related issues based on inquiry. What is missing there, however, is that it has not been clear how scientific inquiry can contribute to make informed decisions. Since making decisions requires value judgment, the problem turned into what the relationship is between scientific inquiry and value judgment.

John Dewey's view that the uses of scientific inquiry can improve students' ability for value judgment provides that missing link between inquiry and decision-making. Inquiry is an active process of knowing by understanding, evaluating, and forming the knowledge. Learning science through inquiry transforms our world view by opening up for action (Kruckeberg, 2006). Inquiry also includes value judgment that is a practical judgment of guiding an action. Therefore, each step of scientific inquiry involves value judgment to decide what to do, and in this way, values influence both external and internal part of science practice. With the help of John Dewey's view, scientific inquiry in K-12 science education can be connected to value judgment, and eventually to decision-making. There, students can learn how to conduct the scientific inquiry and how to make practical judgment during the scientific inquiry. Reflecting the result of their practical judgment, students can evaluate values involved in their decision during the inquiry. Students can learn value judgment while conducting the scientific inquiry and these learning

experiences will help them when they make a personal or civic decision in science-related issues.

Ultimately these learning experiences will lead students to achieve science literacy.

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